NUMERICAL STUDY ON THE PIPE CONTAINING MULTIPLE ALIGNED AXIAL CRACKS

MOHAMAD ZIKRIL HAKIM BIN MD SALEH

Report submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

JUNE 2013

ABSTRACT

Failures due to the multiple cracks become a major concern in the pipeline industry and also in maintaining the pipeline integrity. The predictions of pipeline burst pressure in the early stage are very important in order to provide assessment for future inspection. The effects of the multiple aligned axial cracks on burst pressure of material Grade B was studied through an experimental and numerical simulation. The objectives of this research are to investigate the effects of multiple aligned axial cracks towards the burst pressure. This research focuses on two types of analysis which is experimental and simulations by using material Grade B pipe with outer diameter of 60.5mm, 600mm in length and thickness of 4mm. The burst test is done by applying internal pressure of hydraulic oil continuously at the pipe with artificially machined cracks until the pipe burst. MSC Marc Patran 2008r1 is used as a pre-processor and a solver in the analysis of material Grade B. A half of the pipe was modeled by considering the symmetrical conditions using the same parameter with a pipe that used in the burst test. In both analyses of experiment and simulation, the stress and strain are used as criteria for predicting the failure of the pipe. The result shows that as the length of the cracks increase, the burst pressure is decreased. The assessment method in predicting the burst pressure such as ASME B31G, Modified ASME B31G and DNV-RP-F-101 used as the comparison with the result taken from the analysis.

ABSTRAK

Kegagalan disebabkan oleh plbagai jenis retak menjadi kebimbangan utama di dalam industri perpaipan dan juga dalam mengekalkan integriti perpaipan. Ramalan terhadap tekanan pecah didalam saluran paip pada peringkat awal adalah amat penting dalam usaha untuk menyediakan penilaian untuk pemeriksaan masa depan. Kesan tekanan pecah daripada pelbagai retak sejajar dengan paksi pada bahan Gred B telah dikaji melalui eksperimen dan kaedah unsur terhingga (FE). Objektif kajian ini adalah untuk menyiasat kesan pelbagai retak paksi sejajar terhadap tekanan pecah. Kajian ini memberi tumpuan kepada dua jenis analisis yang merupakan eksperimen dan simulasi dengan menggunakan bahan paip B Gred dengan diameter luar 60.5mm, 600mm panjang dan ketebalan 4mm. Ujian pecah dilakukan dengan mengenakan tekanan dalaman oleh minyak hidraulik dengan berterusan pada paip yang terdapat retak buatan mesin sehingga paip pecah. MSC Marc Patran 2008r1 digunakan sebagai pra-pemproses dan penyelesai dalam menganalisis bahan Gred B. Separuh daripada paip dimodelkan dengan memandangkan keadaan simetri menggunakan parameter yang sama dengan paip yang digunakan dalam ujian pecah. Dalam kedua-dua analisis eksperimen dan simulasi, tekanan digunakan sebagai kriteria untuk meramalkan kegagalan paip. Hasil kajian menunjukkan bahawa semakin panjang kenaikan retak, tekanan pecah akan semakin berkurangan. Kaedah penilaian dalam meramalkan tekanan pecah seperti ASME B31G, Modified ASME B31G dan DNV-RP-F-101 digunakan sebagai perbandingan dengan keputusan yang diambil daripada analisis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

$2c_1$	Crack length
$2c_2$	Crack length
d	Distance between the cracks
OD	Outer diameter
t	Crack thickness

LIST OF ABBREVIATONS

3D	Three Dimensions
ASTM	American Society for Testing and Material
ASME	American Society for Mechanical Engineer
API	American Petroleum Institute
DNV	Det Norske Veritas
RP	Recommended Practice
FEA	Finite Element Analysis
FEM	Finite Element Method

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF RESEARCH

Oil and gas are also called hydrocarbon or petroleum. They come from the underground and provide fuel for machines and vehicles, heating and energy for industries. Hydrocarbons are taken from the ground are a mixture of gases, liquids, semi-solids like waxes and also solids like asphalt, tar and pitch. The oil often been used to provide petrol, diesel, activation fuel and fuel oil. The gas was used to generate electricity, widely used in the industry, and some were converted into synthetic petrol. Oil and gas rise to the earth's surface through the gaps in the rock. But where they cannot seep through or around the rock, they become trapped. Hence, the oil and gas located only several kilometers below the surface, so it just needs to be drilled to retrieve the petroleum [1].

The main problems lie after this process where the transportation of the petroleum. Mostly the drilling process happens at the offshore which is quite far from the land. So in order to make a transfer, the pipe is used as a transfer medium instead of a ship. Basically the pipe had their limit and durability.

So for a long usage, the pipe will get some crack from the corrosion and other effects. Hence, the pipe will not safe enough to transport the petroleum. The pipe might have a leak or may be burst up [2].

In order to overcome the problems, an investigation was made where some research will be conducted as a guideline. The main focus of the research is about the relationship between the length of cracks and the burst pressure. For the pipe properties, it only uses one type of pipe which is pipe with material Grade B as a model to complete the experiment and also as a reference. There are 20 types of cracks that be examined in this research. Then the result that founds from the experiment will be compared with the result from the research.

1.2 PROBLEM STATEMENT

Piping system might have a crack after being used for a long time. It will bring trouble to the industry that used the cracked pipe and also might become dangerous if the pipe fail. This will result in a leaky and also bust up on the pipe. If this happens, not only the industry will suffer from the failure, but also the safety of the workers. The environment around it will be affected too. So it is really important to avoid this happening. One of the options is by using the piping inspection. By using the piping inspection, the inspector will inspect the pipe and search for any cracks and defects or failure. Then the life estimation of the pipe can be defined. So, the pipe can be changed when the life estimation almost expired. This can avoid any failure happen to the pipe during it being used.

There are lots of defects during the service's inspection such as corrosion, single defects, parallel defects and so on. But some of them come in the form of multiple cracks where there are no reliable criteria to predict the failure. The validation of this model also has not been done yet. So it is crucial to validate them and also determine this type of defect [3-4]. Thus, the pipe that contain with several types of multiple aligned axial crack will be tested.

1.3 RESEARCH OBJECTIVES

The aim of this research is about the numerical study on the pipe containing multiple aligned axial cracks. Hence, the objectives of this research are:

1. To analyze the interaction between different cracks length.
2. To predict the failure pressure of different cracks length.
3. To investigate the effect of the distance between the cracks toward the failure pressure.
4. To determine the relationship between the length and the distance between the cracks towards the failure pressure of the pipe.

1.4 SCOPES OF THE RESEARCH

The scopes of the research are as follows:

1. Material used is piped with material Grade B
2. Focusing on different combination of crack length
3. Use MSC Marc Patran 2008r1 for the finite element analysis

1.5 SIGNIFICANT OF THE RESEARCH

The multiple cracks happen in the pipe are really serious agenda. By doing this research, it is hoped that the failure pressure for multiple crack especially the aligned axial crack can be determined. Thus, there is more pipe leakage and also blown up pipe can be reduced since the pipe is already known when it needs to be replaced. The people and also environment as well, will be safer from the danger and also pollutant.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Nowadays, a pipe is a common medium that widely been used all around the world in order to transfer fluid [1]. By using these kind of medium, fluid can be easily transferred and also can save a lot of money and time. There are many industries that using a pipe to transfer fluid such as oil and gas industries and also chemical based industries. Because of there are so many properties of pipe, each of the industries only used the most suitable pipe according to the material that the industry used. This is to ensure the pipe is good enough and also can withstand the fluid that flow through it. As for the pipe itself, it can be used in a period without any problems [1-2].

2.2 USAGE OF THE PIPE

In general, pipe has been used as a medium to transfer fluid from a place to another. This fluid includes water, oil, chemical, steam, smoke and also gas. By using a pipe, the transferring job becomes easier. In the factory, they use pipe to transfer the waste product into a waste tank and also use a pipe to transfer steam, gas and also heat from the boiler to the machine. The pipe also used in transfer oil from the oil rig at the offshore to the base at the land [4]. Usage of pipe is not limited to only transfer fluid but they also can be used as the cooling system like in a radiator and others.

2.3 TYPES OF THE PIPES

There is a lot of pipe that used by the company in all around the world. Each pipe is used based on their mechanical properties which are the better properties means better performance of the pipe and it can be used for a long time.

2.3.1 Copper pipe

Copper pipe is resisting corrosion, so it is commonly used pipe in water supply lines. It costs more than plastic but it lasts. There are two common types of copper pipe. The first one is rigid copper**,** which is coming in three thicknesses. Type M is the thinnest but is strong enough for most uses. Types L and Type K are thicker and used in outdoor and drain applications. Pipes are usually connected with soldered (sweat) fittings and compression fittings can connect the pipe to shut-off valves. The other one is flexible copper**,** which is often used for dishwashers, refrigerator icemakers, and other appliances that need a water supply. It is easy to bend. Sections of flexible copper pipe are joined using either soldered or compression fittings [5-6].

2.3.2 Plastic pipe

Plastic pipe comes as either ABS (acrylonitrile-butadiene-styrene) or PVC (polyvinyl-chloride). Most homes and small industries have plastic pipes and fittings because it's inexpensive and easy to use. ABS, which is this black pipe, was the first plastic pipe to be used in residential plumbing. Today, many areas do not allow ABS in new construction because joints can come loose. Another is PVC, where this white or cream colored pipe is the most commonly used pipe. It's strong, untouchable by chemicals, and seems to last forever. The rating and diameter is stamped right on the pipe. Schedule 40 PVC is strong enough for residential drain lines. CPVC (chlorinated polyvinyl chloride) pipe has the strength of PVC but is heat-resistant, which makes it acceptable in many regions for use on interior supply lines.

Schedule 80 PVC is sometimes used for cold-water supply lines, but it is not allowed in some regions because it is not suitable for hot water [5-6].

2.3.3 Steel pipe

Steel pipe is the most common pipe that has been used in global industries. This is because the material properties of the steel pipe itself. Steel is among the best material in the aspect of durability and long life lasting compared to the other material. This kind of pipe normally used in many industries to transfer fluid such as oil, gas, water, chemical, smoke and others. In steel pipe itself, there are certain levels or grades for differentiating the steel pipe durability. There are various grades of steel, but the common used by industries is X42, X52, X65, X80 and X100 steels [7]. The higher grades mean the high durability of the steel. Table 2.1 shows the mechanical properties of the pipeline steel.

Table 2.1: Mechanical properties of various grades of pipelines steel [7-9]

Mechanical properties (steel)	**X42**	**X52**	**X65**	**X80**	**X100**
Young's modulus (MPa)	20700	20700	20700	20700	20700
Poisson's ratio	0.3	0.3	0.3	0.3	0.3
Yield Strength (MPa)	285	358	456	646	802
Tensile Strength (MPa)	464	551	570	760	891

2.4 DEFECTS IN PIPE

The pipes itself have their own life expectancy. When being installed in a long period at a certain place, the pipe will undergo a process called defects. This defect will make the pipe become unusable and need to be changed to a new one. There are many defects that can be occurring in the piping system. Since this study involves the pipe that being used in the offshore, so the defects are focused on the steel pipe only. The defects can be categorized as follows.

2.4.1 Geometrical Defects

Geometrical defects involve a smaller change in wall thickness than the allowable wall thickness tolerance and result in stress accumulation and concentration [10]. There are many types of geometrical defect such as regular buckle, ovality, wrinkle, and knob. The details of these defects will be explained in the next subsection.

Regular buckle

This is a residual deformation of the pipe wall inside the pipe without sharp edges extending over an area. The possible cause of the origin is commonly external mechanical impact in the pipe [10]. Figure 2.1 shows the condition of the regular buckle.

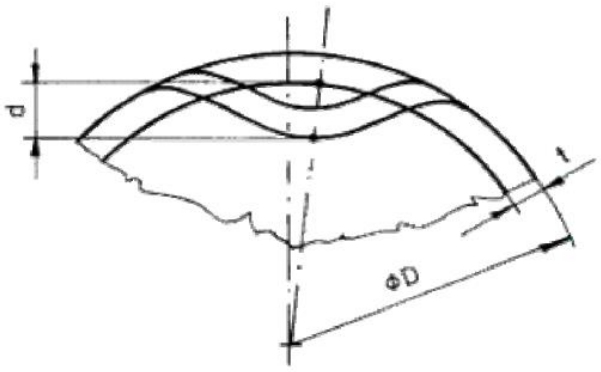

Figure 2.1: Regular buckle [10]

Ovality

This type of defect is a nearly symmetric deviation of the pipe cross-section from the circular shape resulting in elliptical cross-section without sharp break points. The possible cause of these defects is on the pipe manufacturing and also external mechanical impact on the pipe [10]. Figure 2.2 shows the Ovality configuration.

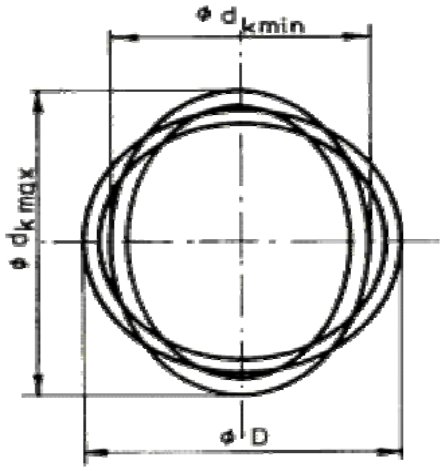

Figure 2.2: Ovality [10]

Wrinkle

From the characteristic of the rippled side of the pipe (number and shape of ripples) the extent of deformation of the opposite side if the pipe can be concluded. The normal cause of this kind of defect is external mechanical impact and also soil movement [10]. Figure 2.3 shows how the wrinkle happens.

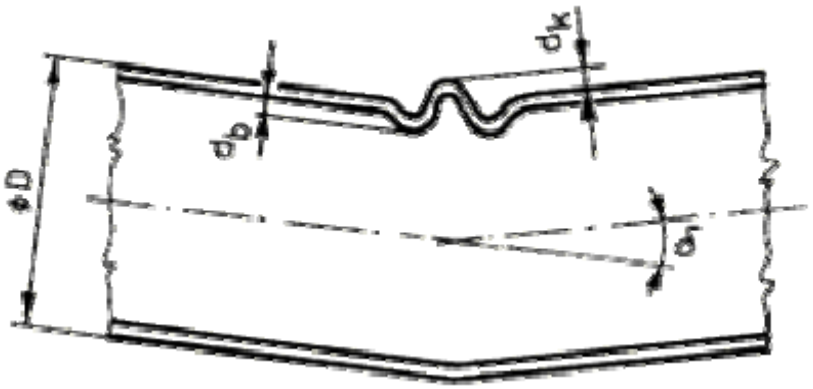

Figure 2.3: Wrinkle [10]

Knob

This is defined as residual deformation of the pipe wall outside the pipe without any sharp edge extending over an area. Possible cause of origin is changed in internal pressure interacting with another defect [10]. Figure 2.4 shows the knob defects.

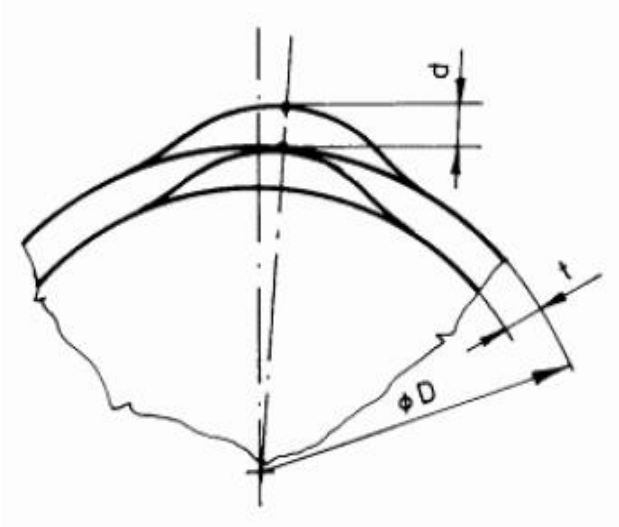

Figure 2.4: Knob [10]

2.4.2 Defects resulting in metal loss

Refer to the greater change in the wall thickness compare to the allowable wall thickness tolerance. This will result in the stress concentration [10]. This also called as corrosion. There are many types of corrosion such as general corrosion, longitudinal corrosion, circumferential corrosion, and spiral corrosion. The description will be stated in the next subsection.

General Corrosion

This is referring to the metal loss extending over a significant area of the pipe resulting in wall thickness decrease. The possible cause of origin is effect of the transported

medium, inappropriate material selection, imperfect coating, damaging coating, and inadequate cathodic protection [10]. Figure 2.5 shows the general corrosion configuration.

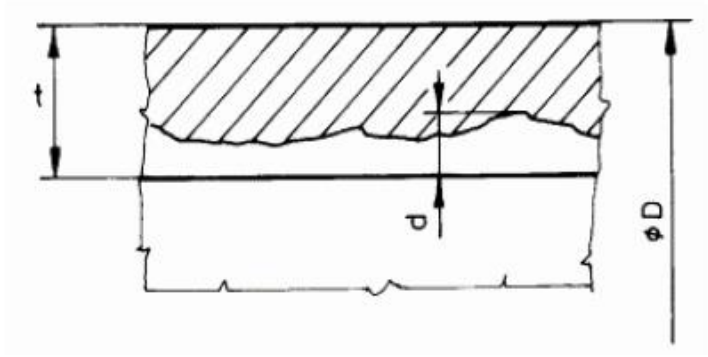

Figure 2.5: General Corrosion [10]

Longitudinal Corrosion

The metal loss parallel with the center line of the pipe resulting in wall thickness decrease having an axial length which exceeds the nominal outside diameter of the pipe and its circumferential size is significantly smaller. Possible cause of origin is an improper welding technology, damaged coating, installation and short circuited structure [10]. Figure 2.6 shows the longitudinal corrosion happen.

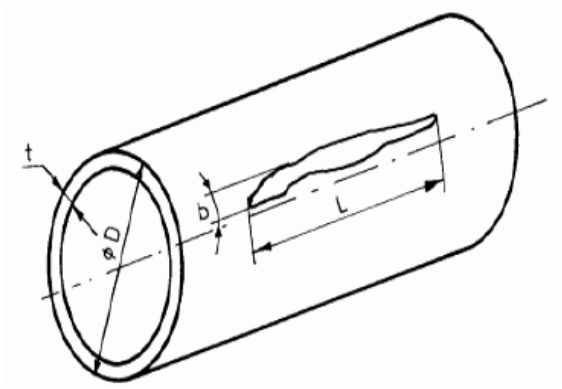

Figure 2.6: Longitudinal corrosion [10]

Circumferential Corrosion

This referring to metal loss perpendicular to the center line of the pipe resulting in wall thickness decrease having a circumferential length which is significantly greater than the width. The possible cause of this origin is like improper welding technology, imperfect coating, damaged coating and also installation. The figure 2.7 shows the configuration for the defects [10].

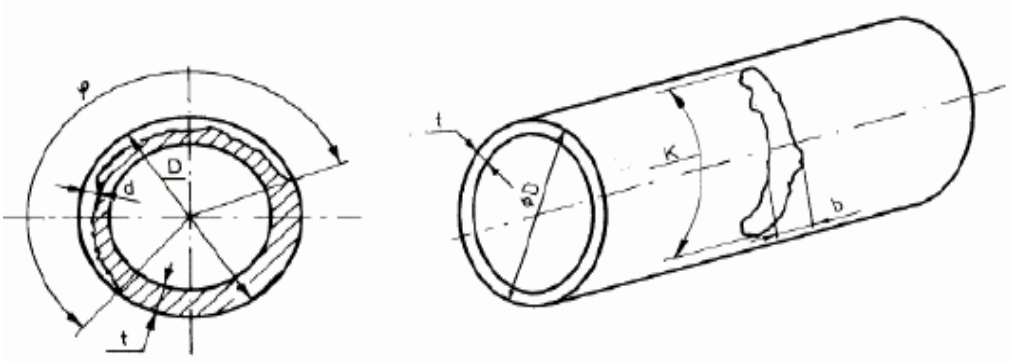

Figure 2.7: Circumferential corrosion [10]

Spiral Corrosion

This is metal loss subtending nearly constant angle to the center line of the pipe, forming a continuous strip or repeating periodically resulting in wall thickness decrease. The possible cause of origin is imperfect coating. Figure 2.8 shows the spiral corrosion defects [10].

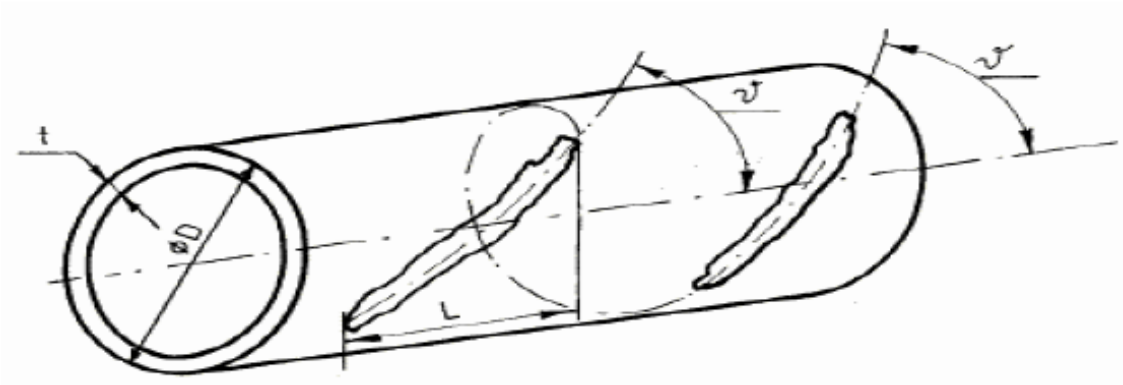

Figure 2.8: Spiral corrosion [10]

Rupture

This defect generally longitudinal discontinuity caused by superficial or near superficial manufacturing defect. The possible cause of origin is at the pipe manufacturing. Figure 2.9 shows the rupture configuration [10].

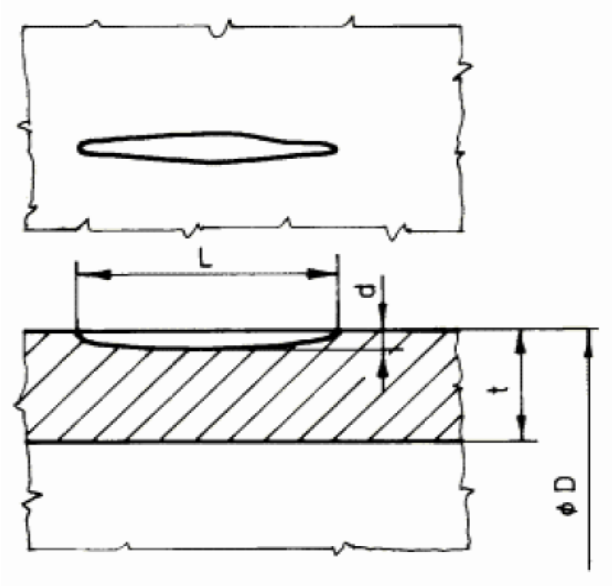

Figure 2.9: Rupture [10]